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Positive affect protects against deficient safety learning during extinction of fear of movement-related pain in healthy individuals scoring relatively high on trait anxiety

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Abstract

From a treatment perspective, it is highly relevant to pinpoint individual *vulnerability factors* for resistance to exposure treatment in highly fearful chronic pain patients. Previous fear conditioning research showed that healthy individuals scoring relatively high on trait anxiety display sustained fear to safety cues during extinction. In the context of fear of movement-related pain this intriguing question has been largely neglected so far. Even more importantly, positive psychological traits such as trait positive affect may function as *protective factors* against the spreading of fear to safe movements and improve exposure treatment outcomes.

In this study, healthy participants completed a trait anxiety and trait positive affect questionnaire and underwent acquisition and extinction of fear of movement-related pain using an experimental voluntary movement paradigm. During acquisition, one movement (CS+) was paired with a painful stimulus, another movement was not (CS-). During extinction, the CS+ was no longer reinforced. Results show failure of fear inhibition to the CS- during extinction in healthy individuals scoring relatively high on trait anxiety or relatively low on positive affect. These findings seem to suggest that safety learning is more vulnerable in healthy people with a high anxious disposition and/or relatively lower levels of positive affect. In addition, this is the first study to show that the negative impact of high trait anxiety on fear inhibition to safe cues during extinction can be countered by high levels of positive affect. These findings may have important clinical implications.

Perspective: Both low positive affect and high trait anxiety are associated with impaired fear inhibition to non-painful movements during fear extinction. Interestingly, high levels of positive affect buffer against the negative impact of trait anxiety. Increasing positive affect during exposure may counter the effects of trait vulnerabilities and improve treatment outcomes.

1. Introduction

Contemporary fear-avoidance models [1, 6, 49, 51] consider pain-related fear as a key factor in the origins and the maintenance of chronic pain disability [7, 16, 25, 43, 44, 53]. In line with this assumption, more specific cognitive-behavioral treatments have been developed that explicitly target pain-related fear, of which exposure in vivo to feared movements has yielded the strongest evidence [3, 8-10, 28, 29, 45, 50]. Accumulating evidence from human fear conditioning research seems to suggest that the pathological marker in anxiety disorders is excessive fear to safety cues (CS-) rather than increased fear to threat cues (CS+) [2, 19-21, 27, 30, 31, 33]. Presumably, impaired discrimination learning and fear overgeneralization play a crucial role in pathological anxiety-related disability. That is, fear is not restricted to specific cues predicting danger, but may spread to a broad range of safety cues, resulting in an increased frequency of fearful responding and/or widespread avoidance behavior. A well-established risk factor for the development of anxiety disorders is trait anxiety [18, 26, 34]. Recently, it has been demonstrated that high trait anxious individuals indeed show prolonged fearful responding to the safety cues leading to impaired extinction [17]. From a treatment perspective, it is highly relevant to pinpoint the individual markers that might constitute a *vulnerability* for resistance to exposure in vivo treatment. In the context of fear of movement-related pain, this intriguing question has been neglected so far both in the clinic as well as in experimental research. In addition, and even more interesting positive psychological traits such as trait positive affect may buffer against the spreading of fear to safe movements and serve as *protective factors* that foster resilience during exposure treatment[5, 13-15, 46]. There is at least one mechanism that can explain the link between trait positive affect and better safety learning: the expectancy of pain. Contingency learning (i.e. pain expectancy learning) and thus the formation of threat and safety beliefs underpin conditioned fear responses. It is known that dispositional optimism[39] and trait positive affect[12] are associated with generalized positive outcome expectancy. Accordingly, not expecting pain as a default would facilitate inhibitory learning. We further assume that, positive traits are associated with low pain expectations, which will lead to low fear of pain and anxiety, which in turn will lead to less pain sensitization. This mechanism is theoretically well supported, and empirical evidence is starting to emerge[22].

We performed a secondary analysis on the data of a conditioning experiment[38] using the Voluntary Joystick Movement (VJM) paradigm[37] in which one proprioceptive Conditioned Stimulus (CS+; left movement) was followed by a painful stimulus (Unconditioned Stimulus; pain-US), and another (CS-; right movement) was not. During the subsequent extinction training, the CS+ movement was no longer reinforced. Participants also completed the trait versions of the State-Trait Anxiety Inventory (STAI-T)[41, 47] and the Positive and Negative Affect Schedule (PANAS)[11, 52]. We expected that 1) healthy individuals scoring relatively high on trait anxiety would display more fear in response to the safe (CS-) movement than relatively low trait anxiety individuals in the beginning of the extinction phase, but that there are no differences in the fear in response to the painful (CS+)movement, 2) healthy individuals scoring relatively high on trait positive affect would show better safety learning (i.e. lower fear responses to the CS-) than individuals with relatively low levels of trait positive affect. Again no such difference is anticipated for the conditioned fear response to the CS+ movement, 3) high trait positive affect might buffer the negative impact of high trait anxiety on safety learning during extinction.

2. Methods

2.1. Participants

The data of fifty-six healthy participants (49 women, 7 men; M_{age} = 19 years, SD_{age} = 2.80, range = 16-32 years) collected in an experiment investigating acquisition, extinction and return of fear of movement-related pain with the VJM was used to test the deficient safety learning hypothesis during extinction. In return for their participation (a) 36 psychology students of the University of Leuven received course credits, and (b) 20 volunteers were paid €10. Participants confirmed not to suffer from respiratory or cardiovascular diseases, neurological diseases (e.g., epilepsy), psychiatric disorders or any other minor or major illness, chronic pain, nor to be pregnant. Additional exclusion criteria were hearing problems and pain at the dominant hand or wrist. The experimental protocol was approved by the Ethical Committee of the Faculty of Psychology and Educational Sciences of the University of Leuven. All participants signed the informed consent form, which explicitly stated that they were allowed to decline participation at any time during the experiment. Note that a subset of the data of this experiment has been published in a previous issue of this journal[38] The main aims of the prior publication were twofold: 1) to investigate whether mere intention to perform painful movements can start to elicit fear of movement-related pain, and 2) to investigate the return of fear of movement-related pain in the VJM task. In order to answer our first question, we let people verbally express the direction they were going to move in (left/right) on every trial and inserted a variable intention delay during which participants were requested to stand ready and actively prepare to perform the movement of their choice as soon as the starting signal appeared in the middle of the screen. During this intention delay, we presented startle probes to assess the fear elicited during the anticipation or intention to perform the (non-)painful movements. Results showed that merely thinking about performing a painful movement can indeed trigger fear of movement-related pain, as indicated by higher startle amplitudes during the intention delay on CS+ trials than on CS- trials. To answer our second question, we inserted a reinstatement phase (i.e. the presentation of two unsignaled pain-USs) after extinction in the experimental group, but not in the control group. We found that self-reported fear of movement-related pain re-appeared for both movements in the experimental group only. In the startle measures during the movement and the intention, this effect did not materialize. The main analyses of the present paper however focus on the extinction phase only, and more in particular on the safety learning and how this depends on individual differences (PA and TA). Note that the description of the startle measure was omitted in this paper for sake of brevity and clarity.

2.2. Stimulus material

We applied a differential conditioning procedure modeled to the Voluntary Joystick Movement (VJM) paradigm developed by Meulders, Vansteenwegen and Vlaeyen[38]. We used two proprioceptive stimuli i.e., moving a (Logitech Attack 3) joystick to the left and to the right as CSs. The US was an electrocutaneous stimulus (2 ms duration), which was delivered by a commercial constant current stimulator (DS7A, Digitimer, Welwyn Garden City, England) through surface Sensormedics electrodes (8 mm) filled with K–Y gel that were attached to the wrist of the dominant hand. During a calibration procedure, the stimulus intensity was individually set for each participant, targeting a subjective stimulus intensity of *'8'* referring to a stimulus that is "*significantly painful and demanding some effort to tolerate*" on a scale with '*1*' indicating "*you feel something but this is not painful, it is merely a sensation*" and '*10*' indicating "*the worst imaginable pain*" (mean subjective stimulus intensity = 7.99, SD = 0.28, range 7–9). The mean stimulus intensity was 25.50 mA (SD = 10.82, range 8–72 mA). The experiment was run on a Windows XP computer (Dell Optiplex 755) with 2 GB RAM and an Intel Core2 Duo processor at 2.33 GHz and an ATI Radeon 2400 graphics card with 256 MB of video RAM, using Affect 4.0 [42].

2.3. Measures

2.3.1. Questionnaires

Before participating in this experiment, participants' trait anxiety (TA) was measured using the Dutch trait version of the State-Trait Anxiety Inventory (STAI-T) [41, 47]. Participants were asked to indicate to what extent they are *generally* experiencing the feelings described by 20 items on a 4-point response scale ranging from "almost never" to "almost always". Ten items are reverse-scored before summing all the individual item scores to obtain the total score (range 20-80). Participants' trait positive affect was measured using the positive affectivity scale of the Dutch trait version of the Positive and Negative Affect Schedule (PANAS)[11, 52]. Participants are asked to indicate to what extent, *in their normal daily life*, they experience the feelings defined by 20 descriptors using a 5-point response scale ranging from "very little" to "a lot". Ten items describe positive feelings and assess positive affectivity (PA; range 10-50) and 10 items describe negative feelings and assess negative affectivity (NA; range 10-50).

2.3.2. Self-reported fear of movement-related pain

After each block of eight movements (4 CS+/4 CS-), participants answered the following question: "*How afraid were you to perform the left/right movement?*" on an 11-point Likert scale ranging from '0' to '10' with anchors '*not fearful at all'* to '*the worst imaginable fear'*.

2.4. Procedure

The VJM experiment consisted of several phases: preparation, practice, fear acquisition, and fear extinction. During acquisition, one movement (CS+) was consistently followed by the pain-US and the other movement (CS-) was never followed by the pain-US. Note that the direction of joystick movement that served as the CS+ and the CS- was counterbalanced across participants. During extinction however, the CS+ movement was no longer followed by the pain-US. During all experimental phases, participants freely chose in which direction they were going to move, and verbally expressed their choice on each trial before actually moving.

2.4.1. Preparation

Participants were informed (orally and in writing) that painful electrocutaneous stimuli (pain-US) would be administered during the experiment. After providing informed consent, participants went to the experimental room. After placing the stimulation electrodes, the intensity level of the pain-US was selected following the calibration procedure (see *'2.2. Stimulus material'* section).

2.4.2. VJM practice

Before initiating the practice phase, participants received detailed instructions about the experimental VJM task. They were told that their main task was to move the joystick eight times (i.e., 4 left/4 right) as quickly and accurately as possible when prompted by a starting signal ''+'' (fixation cross presented in the middle of the computer screen), in whatever order they freely chose. Counter bars, divided in four equal segments, were positioned on the left and right side of the computer screen and a successful movement always resulted in changing the color of one segment of the corresponding counter bar. That way, participants could instantly ascertain how many movements in each direction remained to be carried out (see Figure 1). During the practice phase, two blocks of eight trials were run, no pain-USs were presented and the experimenter provided online verbal feedback about the task performance.

2.4.3. Fear of movement-related pain acquisition

This phase was largely identical to the practice phase with the exception that 1) pain-USs were presented, 2) three blocks of eight trials were run instead of two blocks, and 3) instructions now emphasized to pay close attention to the starting signal "+" and to respond as fast and accurately as possible upon its presentation. The pain-US was presented on each CS+ trial, immediately after the CS+ movement was executed, but not on the CS- trials. Note that participants were never informed about the contingencies between the joystick movements

(CSs) and the pain-US. After each conditioning block, fear of movement-related pain of the CSs was rated on a computerized numerical 11-point scale.

2.4.4. Fear of movement-related pain extinction

By and large, this phase was identical to the acquisition phase, except that (a) no pain-USs were presented anymore after the CS+ movement, and (b) five blocks of eight trials were run.

2.5. Experimental setting

Participants were seated in an armchair (0.6 m screen distance) in a sound-attenuated and dimmed experimental room, adjacent to the experimenter's room. Further verbal communication was possible through an intercom system; the experimenter observed the participant by means of a closed-circuit TV installation and computer monitors.

2.6. Data analysis

In this paper, we aimed to systematically study how fear of movement-related pain ratings for two types of movements (CS+/CS-) change during the extinction phase and to what extent this change pattern depends on the person’s level of positive affect and/or trait anxiety. Figure 2 shows the self-reported fear of movement-related pain at the end of the acquisition phase (a3) and during the five blocks of the extinction phase (e1-5) for healthy people scoring relatively high vs. low on both TA and PA (based on a median split). Acquired differential learning (a3) does not seem to differ depending on these trait variables. Interestingly, however, healthy people with relatively low PA or relatively high TA show increased fear in response to the safe (CS-) movement in the beginning of the extinction phase (e1) as compared to the end of acquisition (a3) and this effect seems to disappear gradually throughout the extinction phase. In contrast, there does not seem to be any difference in fear to the CS+ movement in the beginning of the extinction phase. More specifically, we tested three main hypotheses: 1) do healthy individuals scoring relatively high on TA and healthy individuals scoring relatively low on PA report more fear to the safe CS- movement at the beginning of extinction as compared with the end of acquisition, but not to the painful CS+ movement? 2) do the slopes of the fear ratings for the CS- movement during the course of extinction differ for people with relatively high vs. low TA and relatively high vs. low PA, with steeper slopes for high TA and low PA? 3) does relatively high PA buffer the negative impact on safety learning in healthy individuals scoring relatively high on TA? A few remarks need to be placed in the margin to clarify these hypotheses. First, with respect to the traits examined, we do not believe in the rigid expression of traits, that is, the same expression in any kind of situation, but rather in a flexible expression that depends on the trait-environment interaction ("strong vs. weak situation")[32] – an idea that has received plenty of empirical support. We assume that the emergence of individual differences would be facilitated in weak or ambiguous situations, in this case, the uncertainty is greatest at the beginning of the extinction phase, as the contingencies change. Second, the questionnaire scores are not truly "high" from a clinical point of view, but it rather concerns "relatively" high and low scores with this healthy study sample as a reference. Furthermore, the current analyses involve continuous measures of the trait variables and thus the conclusions should be understood in terms of associations between continuous variables. However, in order to visualize and discuss the effects, we labeled the healthy individuals scoring ±2SD above the reference mean as being relatively low/high on the traits under investigation (see online supplementary material, Table S1). To test these hypotheses, we defined three multilevel regression models: one to test the effect of TA, PA, and the combined effect of TA and PA respectively on fear of movement-related pain ratings during the extinction phase (see online supplementary material for the detailed statistical model description). The effects included in each model were estimated simultaneously using the SAS procedure MIXED[24, 48]. Although the models include specific regression coefficients for each of the movement types (CS+ and CS-), based on our theoretical framework, as well as the visual inspection of Figure 2, it is expected that the differences during extinction learning will be related to the CS- rather than to the CS+. Follow-up contrasts were calculated to test our a priori hypotheses.

Note that each of these models is rather well able to predict subjects' fear of movement-related pain ratings as they explain 77% of the variance in the observed fear of movement-related pain reports. Including a random subject effect in the model to account for different average fear of movement-related pain ratings across subjects is clearly important as, for each model, a considerable part of the variability in the fear of movement-related pain ratings is due to differences between subjects. In particular, for each model $\sigma_\theta^2/(\sigma_\theta^2+\sigma_\varepsilon^2) = .53$, which means that 53% of the variability in the ratings is due to differences among subjects. Furthermore, when omitting the random subject effect, the variance explained in the fear of movement-related pain rating drops from 77% to 48% for each of the models.

3. Results

3.1. Descriptives of questionnaires and pain-US intensity measures

Table S2 (see online supplementary material) displays the descriptive statistics for the scores on the questionnaires and the pain stimulus intensity measures (self-reported and measured in mA). We did not observe a significant relation between the TA or PA scores and these intensity measures (see online supplementary material, Table S3). However, we did find a significant negative correlation between TA and PA ($r = -0.44$, $p < .001$) on the one hand, and a positive correlation between TA and negative affect (NA) ($r = 0.73$, $p < .001$) on the other hand.

3.2. Hypothesis 1: Effect of positive affect and trait anxiety on the fear of movement-related pain ratings at the start of extinction

As a first step, we wanted to test the hypothesis that healthy individuals scoring relatively high on TA and healthy individuals scoring relatively low on PA report increased fear of movement-related pain to the safe CS- movement at the start of extinction as compared to the end of acquisition, but not to the painful CS+ movement. Table S1 (see online supplementary material) is the frequency table providing information about the number of people categorized as scoring "relatively high" and "relatively low" on both trait variables, with this healthy study sample as a reference. Table 1 presents the results for the multilevel regression models including PA and Table 2 presents the results for the multilevel regression models including TA. We first discuss the results of the model that includes PA. As can be seen in Table 1, individuals with an average PA score report significantly less fear of movement-related pain for the CS+ movement, in the beginning of the extinction phase (e1) as compared with the end of the acquisition phase (a3), ($\mu^{(+)} = -2.39$, p<.0001). The opposite is true for the CS- movement, that is, individuals with an average PA score report more fear of movement-related pain during the first block of the extinction phase than during the last block of the acquisition phase ($\mu^{(-)} = 1.23$, p<.0001). This increase in fear of movement-related pain ratings is also observed in individuals with low levels of PA, namely a PA score of two standard deviations below average, ($\mu^{(-)} - 2\beta_{PA}^{(-)} = 2.02$, p<.01), but not for those with high levels of PA, that is, a PA score two standard deviations above average, ($\mu^{(-)} + 2\beta_{PA}^{(-)} = 0.45$, p=.47).

For the model that includes TA, we observe a similar effect for the CS+ movement, and a very similar but reverse effect for the CS- movement. As can be seen in Table 2 in the left panel, individuals with an average TA score report significantly less fear of movement-related pain for the CS+ movement, in the beginning of the extinction phase (e1) as compared with the end of the acquisition phase (a3), ($\mu^{(+)} = -2.39$, *p*<.0001). The opposite is true for the CS- movement, that is, individuals with an average TA score report more fear of movement-related pain during the first block of the extinction phase than during the last block of the acquisition phase ($\mu^{(-)} = 1.23$, *p*<.0001). This increase in fear of movement-related pain ratings is also observed in individuals with relatively high levels of TA, namely a TA score of two standard deviations above average, ($\mu^{(-)} + 2\beta_{TA}^{(-)} = 2.37$, *p*<.0001), but not for those with low levels of TA, that is, a TA score two standard deviations below average, ($\mu^{(-)} - 2\beta_{TA}^{(-)} = 0.09$, *p*=.88).

3.3. Hypothesis 2: Differences in fear of movement-related pain ratings across extinction blocks with varying levels of positive affect and trait anxiety

The second step was to assess whether the slopes for the CS- movement during the course of extinction differ for healthy people with relatively high vs. low TA and high vs. low PA. Again, we first discuss the results of the multilevel regression model that includes PA. As can be seen in Table 1, fear of movement-related pain ratings significantly decrease in subsequent blocks of the extinction phase for both the CS+ movement ($\beta_{T}^{(+)} = -.51$, *p*<.0001) and the CS- movement ($\beta_{T}^{(-)} = -.27$, *p*<.0001) for individuals with an average PA score. However, the decrease in fear of movement-related pain ratings per block for the CS+ movement is much stronger than for the CS- movement ($\beta_{T}^{(+)} - \beta_{T}^{(-)} = -.25$, *p*<.01). This makes sense, since the CS+ and not the CS- movement started to elicit conditioned fear responding during the acquisition and is now gradually being extinguished due to the absence of the pain-US. As expected, there is no significant interaction between PA and the trend variable for the CS+ movement ($\beta_{TxPA}^{(+)} = .10$, *p* =.15). This means that fear of movement-related pain ratings decrease at the same rate for individuals with different PA levels. Interestingly, however there is a significant positive interaction between the trend variable and PA ($\beta_{TxPA}^{(-)} = .16$, p <.05) for the CS- movement. To further interpret the nature of this interaction effect, we plotted the predicted relationship between the trend variable and the fear of movement-related pain ratings for individuals with varying levels of PA. Figure 3 displays the linear change in fear of movement-related pain ratings during extinction for individuals with varying levels of PA, namely an average level of PA, a PA score of one or two standard deviations above average, and a PA score of one or two standard deviations below average. As shown in Figure 3, fear of movement-related pain ratings are decreasing in subsequent blocks during extinction for subjects with average levels of PA (see Table 1, $\beta_{T}^{(-)} = -0.27$, p <.0001) and for individuals with lower levels of PA, but they are not significantly decreasing for individuals with a PA level of one standard deviation above average (see Table 3, $\beta_{T}^{(-)} + \beta_{TxPA}^{(-)} = -0.11$, p =.26) or for individuals with a PA level of two standard deviations above average (see Table 3, $\beta_{T}^{(-)} + 2\beta_{TxPA}^{(-)} = 0.05$, p =.72).

As can be seen in Table 2 and Figure 4, the results for the multilevel regression model including trait anxiety (TA) reveals the reverse relationship. Again, fear of movement-related pain ratings significantly decrease in subsequent blocks of the extinction phase for both the CS+ movement ($\beta_{T}^{(+)} = -0.51$, p<.0001) and the CS- movement ($\beta_{T}^{(-)} = -0.27$, p<.0001) for individuals with an average TA score. This decrease in fear of movement-related pain ratings per block is much stronger for the CS+ movement than for the CS- movement $(\beta_{T}^{(+)} - \beta_{T}^{(-)} = -0.25, p < .01)$. There is no significant interaction between TA and the linear trend variable for the CS+ movement ($\beta_{TxTA}^{(+)} = -0.13$, p =.06). This means that fear of movement-related pain ratings decrease at the same rate for individuals with different TA levels. Interestingly, there is again a significant interaction between the trend variable and TA

($\beta_{TxTA}^{(-)} = -0.16$, p <.05) for the CS- movement. For the CS- movement, fear of movement-related pain ratings significantly decrease in subsequent blocks for individuals with an average TA level (see Table 2, $\beta_{T}^{(-)} = -.27$, p<.0001), but they do not significantly decrease for individuals with a TA level one standard deviation below average (see Table 3, $\beta_{T}^{(-)} - \beta_{TxTA}^{(-)} = -.11$, p=.23) or for individuals with a TA level two standard deviations below average $(\beta_{T}^{(-)} - 2\beta_{TxTA}^{(-)} = 0.04, p = .78)$, (see Table 3).

Finally, for the multilevel regression model that includes both PA and TA (see Table 4) results are again very similar in that, for the CS- movement, fear of movement-related pain ratings significantly decrease in subsequent blocks for subjects with an average PA and TA level ($\beta_{T}^{(-)} = -.27$, p<0.0001), but they do not significantly decrease in subsequent blocks if either the PA level or the TA level of the subject is one standard deviation above/under average (and the score for the other variable is an average one), (see Table 5, $\beta_{T}^{(-)} + \beta_{TxPA}^{(-)} = -.15$, p=.12 and, $\beta_{T}^{(-)} - \beta_{TxTA}^{(-)} = -.16$ p=.10, respectively).

3.4. Hypothesis 3: Does high positive affect buffer the negative impact on safety learning in healthy individuals scoring relatively high on trait anxiety?

Finally, we tested the intriguing hypothesis whether relatively high levels of PA might maintain safety learning during extinction in healthy individuals with a vulnerability, namely relatively high levels of TA. In order to answer this question we conducted additional planned comparisons in the model including both PA and TA (see Table 4). The moderated interaction of interest is depicted in Figure 5. First of all, as can be seen in Figure 5, individuals with high levels of TA (i.e. two standard deviations above average) and low levels of PA (i.e. two standard deviations below average) $(\mu^{(-)} + 2\beta_{TA}^{(-)} - 2\beta_{PA}^{(-)} = 2.56, p < .001)$ or average levels of PA ($\mu^{(-)} + 2\beta_{TA}^{(-)} = 2.22$, p<.01) report significantly increased fear of movement-related pain to the CS- movement in the beginning of extinction phase as compared with the end of acquisition, but individuals with both a high level of TA and a high level of PA (i.e. two standard deviations above average) do not ($\mu^{(-)} + 2\beta_{TA}^{(-)} + 2\beta_{PA}^{(-)} = 1.88$, p=.09). In addition, the slope of the linear trend variable for the CS- movement is significantly decreasing for individuals with high levels of TA (i.e. two standard deviations above average) and low levels of PA (i.e. two standard deviations below average) ($\beta_{T}^{(-)} + 2\beta_{TxTA}^{(-)} - 2\beta_{TxPA}^{(-)} = -0.70$, p<.0001) or average levels of PA $(\beta_{T}^{(-)} + 2\beta_{TxTA}^{(-)} = -0.48, p < .01)$, but not for individuals with both high levels of TA and high levels of PA (i.e. two standard deviations above average) ($\beta_{T}^{(-)} + 2\beta_{TxTA}^{(-)} + 2\beta_{TxPA}^{(-)} = -0.25$, p=.34), (see Table 5).

4. Discussion

Clinical anxiety has been associated with overgeneralized fear to realistically non-dangerous stimuli (i.e. safety cues)[31, 32]. Delayed discrimination learning or prolonged generalization of fear responses to safety cues may be crucially involved in making anxiety disorders so incapacitating. Recently, it has been demonstrated that high trait anxious individuals do not display differences in the extinction of danger cues (CS+) but especially show prolonged fear to the safety cues (CS-) leading to impaired differential extinction[17]. From a treatment perspective, it is highly relevant to pinpoint the individual markers that might constitute a *vulnerability* for resistance to exposure treatment in highly fearful chronic pain patients. Fear of pain as a major predictive factor in the development and maintenance of disabling musculoskeletal chronic pain has been targeted in exposure-based treatment recently[8-10], however, individual vulnerability factors that might encumber this treatment have been largely neglected in this field so far. On the other hand, positive psychological traits such as trait positive affect may buffer against the spreading of fear to safe movements and serve as protective factors that are beneficial for the outcome of exposure treatment.

This study addresses this intriguing safety deficiency learning hypothesis in healthy individuals scoring relatively low *vs.* high on trait anxiety. In addition, we wanted to ascertain whether the opposite pattern is present in healthy individuals scoring relatively low *vs.* high on trait positive affect. First, we aimed to determine whether disconfirmation of the relationship between a certain movement and a painful outcome (i.e., beginning of extinction as a model for exposure treatment) effects fearful responding to the safe movement differentially, depending on the level of trait anxiety and the level of positive affect. Second, we wanted to assess whether the slopes (i.e. the rate of safety learning) for the CS- movement during the course of extinction differ for healthy people with relatively low *vs*. high trait anxiety and relatively low *vs*. high positive affect. Third, and most interestingly, we wanted to determine whether positive affect serves as a buffer against deficient safety learning in high trait anxiety individuals. For this purpose, the data of a published study[38] were re-analyzed. Participants completed the STAI-T[41, 47] and PANAS[11, 52] and underwent an acquisition and extinction procedure. During acquisition training, one movement (CS+) was consistently paired with a painful stimulus (pain-US) and another was not (CS-). During extinction training, the CS+ was no longer reinforced by the pain-US. Fear responding was assessed through verbal fear ratings.

First, the results indicate that "high" trait anxious people display a failure of fear inhibition in response to the safe, non-painful movement in the beginning of the extinction, which lingers on throughout the rest of this phase. This corroborates previous findings[17]. This failure of inhibition to the safe movement following a shift in CS-US contingency seems to suggest that highly anxious individuals require more resources and effort to actively suppress their primary fearful responses. However, they do seem to be able to inhibit their fear response to the threatening, painful movement to the same extent as "low" trait anxious individuals. The disconfirmation of the relationship between the fearful movement (CS+) and the painful outcome (US) seems to reduce the safety value of the CS- as well. These findings suggest that healthy individuals with higher levels of trait anxiety are implementing a worst case scenario logic, that is, "*if the CS+ is not threatening anymore, the CS- might not be safe anymore either"* or "*if the CS+ is not the threat anymore, something else bad might happen*".

Second, a reverse pattern was observed for trait positive affect, that is, "low" trait positive affect individuals show a release of fear inhibition (i.e. increased fear of movement-related pain reports) to the safe movement in the beginning of the extinction phase. This effect is not observed for people with "high" levels of positive affect. Again, the slopes during the course of extinction indicate a continued deficiency in fear inhibition to the safe movement for low trait affect individuals. To our knowledge this is the first study to demonstrate the effect of trait positive affect on safety learning during fear extinction.

Third and even more interestingly, we found that high positive affect could serve as a buffer for the detrimental effects of "high" trait anxiety on safety learning during extinction. These findings have at least three important implications for clinical treatment of fear of movement-related pain and chronic pain disability. *First*, patients with high trait anxiety should be identified at the onset of the treatment process. Chronic pain patients with high fear of pain do not necessarily score high on trait anxiety. Closely related is the distinction between fear and anxiety[4]. Whereas specific fear refers to a phasic response to an identifiable imminent threat as is typically observed in "kinesiophobia" (e.g., specific movement that is feared due to its association with increased pain), anxiety is a more free-floating and general form of distress in the absence of impending danger (e.g., constant fear to re-injure oneself)[4]. If patients have high levels of this more generalized anxiety (measured with STAI-T or other tools), this might be an indicator for deficient safety learning. We further speculate that increasing state positive affect at the start of a treatment session might counter the destructive effects of trait vulnerabilities and improve exposure treatment outcomes. Future research should focus on the possibility that increasing state positive affect (e.g., best possible self exercise; BPS)[35, 40] might also counteract the spreading of fear to (previously) safe activities/movements during extinction learning in these vulnerable individuals. *Second*, these results suggest that vulnerable individuals will benefit from exposure to not just movements/activities that are ranked high on their idiosyncratic fear hierarchy, but also to those that are ranked lower, which might seem paradoxical at first sight. In these individuals the exposure to activities that are less threatening may prevent a possible spreading/shift of fear and avoidance towards previously non-threatening movements during and after exposure treatment. *Third*, it has been previously reported that positive emotions have an attenuating effect on pain intensity[22, 23]. Given that fear of movement-related pain mediates pain intensity[36], implementing positive mood induction (e.g., BPS exercise[35, 40]) during exposure might lower the pain experience itself through more adequate inhibition of fear to non-threatening elements in the treatment context.

Methodological strengths of the current study are at least three-fold. An important merit of this study is that it is the first to demonstrate impaired fear inhibition in healthy individuals scoring relatively high on trait anxiety in a fear conditioning paradigm using dynamic proprioceptive stimuli (e.g., joystick arm movements) instead of more static exteroceptive (e.g., auditory or visual) stimuli. Basically, we were able to extend the findings on deficient safety learning to the field of pain, which might be particularly relevant to spreading of pain-related fear in chronic pain. Second, this study focuses on resilience and not merely on vulnerability during exposure treatment. This is the first experimental study on (extinction of) fear of movement-related pain that demonstrates that a positive trait can counteract the detrimental effect of a vulnerable trait i.e. trait anxiety. Finally, we used multilevel regression analyses including a random intercept parameter to capture individual differences. Such models treat the trait variables as continuous variables which maximizes the use of information as compared with for example a median split model leading to a favorable model fit and high portion of explained variance ($R^2 = .77$). Further, we specified a model that incorporates both trait anxiety and trait positive affect, and we corrected for the level of learning at the end of acquisition.

Some limitations should be outlined as well. First, this experiment was not specifically designed to study individual differences, and since we used a healthy study sample, trait questionnaire scores might not be extremely high and low in clinical terms. In order to draw firm conclusions regarding the effect of these trait variables, future research should systematically select a sample including individuals extreme low *vs.* extreme high on both trait anxiety and positive affect. Second, we recognize that given the few subjects categorized as relatively high and low on both traits, the design might have been underpowered to detect some unpredicted effects (e.g., on the CS+ movement). On the other hand, the robust and significant effects in a small number of subjects without extreme scores, can be seen as a strength as well, because one could argue that these effects would be more pronounced in people with more extreme questionnaire scores.

To conclude, we demonstrated that trait anxiety and positive affect influences fear inhibition to a safe, non-painful movement during extinction, that is, healthy individuals scoring relatively high on trait anxiety and relatively low on trait positive affect show impaired safety learning during extinction. Interestingly, this is the first study to show that the negative impact of high trait anxiety on fear inhibition to safe cues during extinction can be countered by high levels of positive affect. These findings may have important clinical implications.

5. Disclosures

Ann Meulders (AM) is a postdoctoral researcher of the Research Foundation, Flanders, Belgium (FWO Vlaanderen). This study was also supported by the Odysseus Grant ‘‘The Psychology of Pain and Disability Research Program’’ funded by the Research Foundation, Flanders, Belgium (FWO Vlaanderen) and an EFIC-Grünenthal Research Grant to AM. These data were presented as a poster at the 7th World Congress of Cognitive and Behavioral Therapies (WCBCT), Lima, Peru. The authors report no conflict of interest.

6. Acknowledgments

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8. Figure Captions

Figure 1. Visual feedback provided during the practice phase (upper panel) and during the acquisition and extinction phases (lower panel).

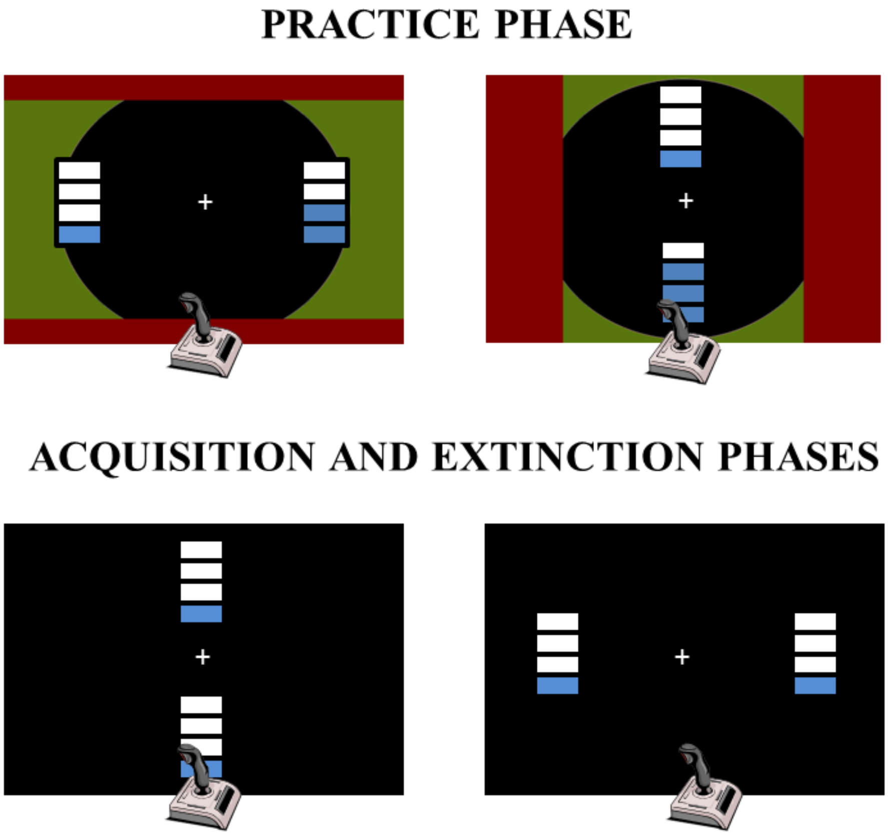
Figure 2. Mean fear of movement-related pain ratings (+SE's) in response to the CS+ and the CS- at the end of the acquisition phase (a1) and during the five blocks of the extinction phase (e1-e5) for healthy individuals A. scoring relatively high and low on trait anxiety, and B. scoring relatively high and low on trait positive affect. Note – for graphic purposes we used a median split procedure to create the groups.

Figure 3. Relationship between fear of the CS- movement during the extinction phase (relative to the last block of the acquisition phase) for individuals with varying levels of trait positive affect.

Figure 4. Relationship between fear of the CS- movement during the extinction phase (relative to the last block of the acquisition phase) for individuals with varying levels of trait anxiety.

Figure 5. Relationship between fear of the CS- movement during the extinction phase (relative to the last block of the acquisition phase) for individuals with relatively high trait anxiety and varying levels of trait positive affect.

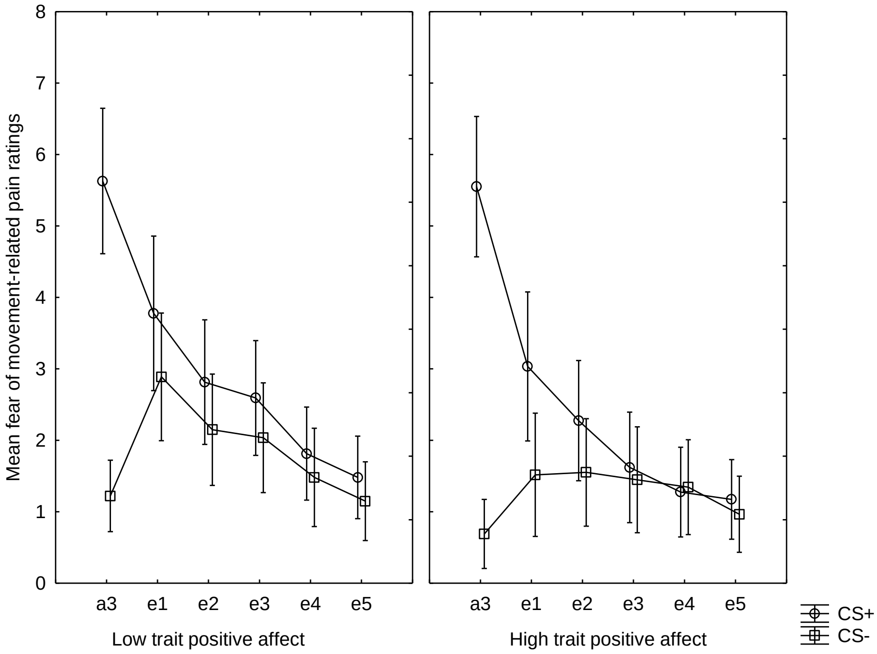
Figure 1. Visual feedback provided during the practice phase (upper panel) and during the acquisition and extinction phases (lower panel).



Note – During the practice phase (upper panel), valid target regions were colored green (left/right), and invalid target regions were colored red. A fixation cross in the middle of the screen, "+", served as the starting signal to initiate a movement. A successfully performed movement resulted in coloring one segment of the corresponding counter bar blue. That way, participants could easily ascertain how many movements ought to be carried out. During the acquisition and extinction phase these target regions were no longer visible (lower panel).

Figure 2. Mean fear of movement-related pain ratings (+SE's) in response to the CS+ and the CS- at the end of the acquisition phase (a3) and during the five blocks of the extinction phase (e1-e5) for A. high and low trait positive affect individuals, and B. high and low trait anxious individuals. Note – for graphic purposes we used a median split procedure to create the groups.

A. Median split for trait positive affect



B. Median split for trait anxiety

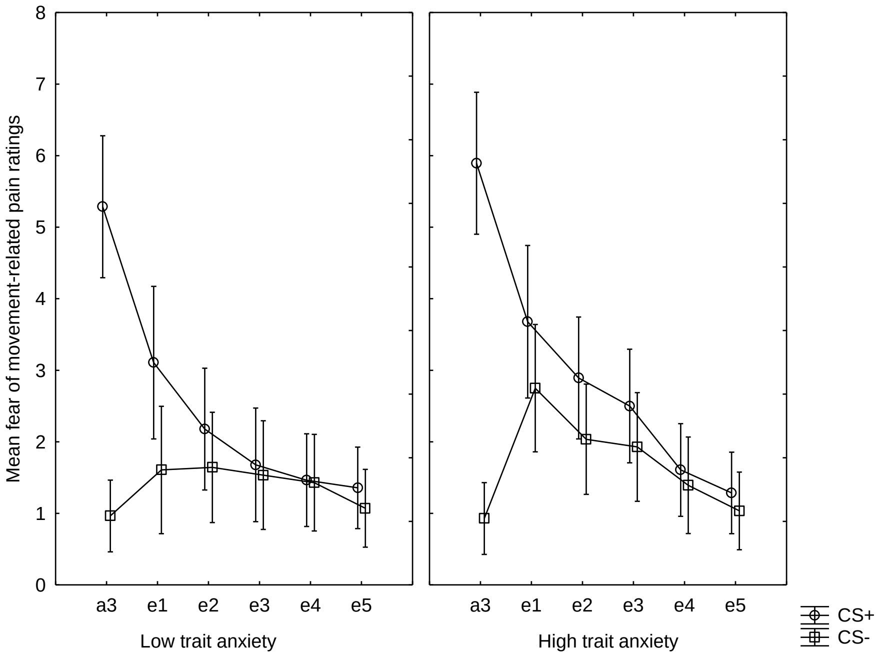


Figure 3. Relationship between fear of the CS- movement during the extinction phase (relative to the last block of the acquisition phase) for individuals with varying levels of trait positive affect.

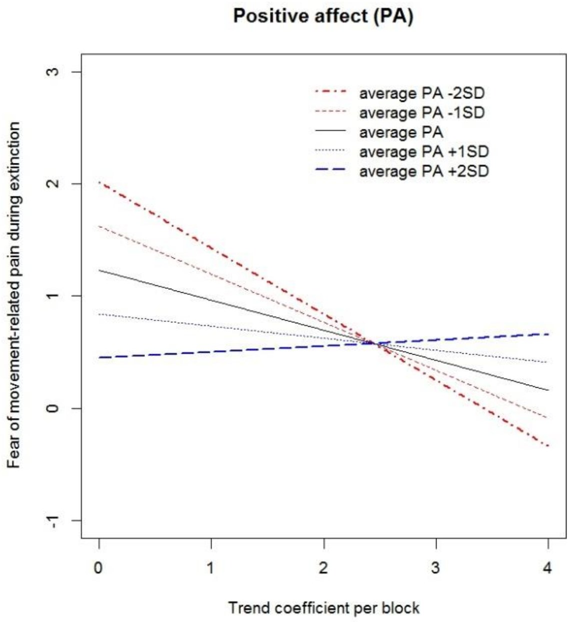


Figure 4. Relationship between fear of the CS- movement during the extinction phase (relative to the last block of the acquisition phase) for individuals with varying levels of trait anxiety.

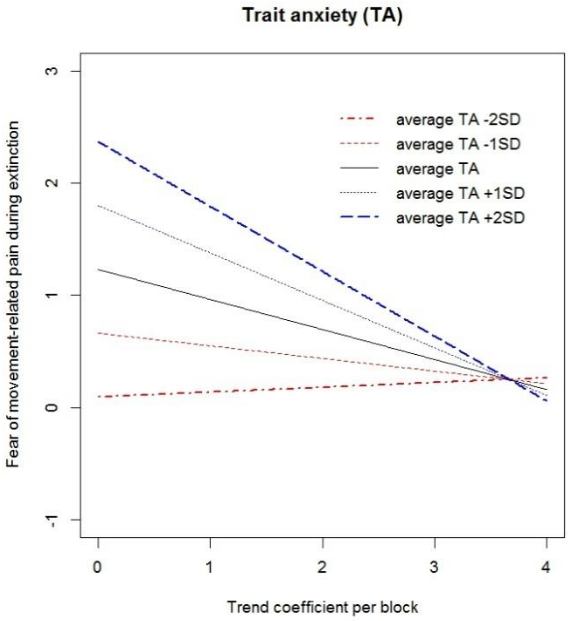


Figure 5. Relationship between fear of the CS- movement during the extinction phase (relative to the last block of the acquisition phase) for individuals with high trait anxiety and varying levels of trait positive affect.

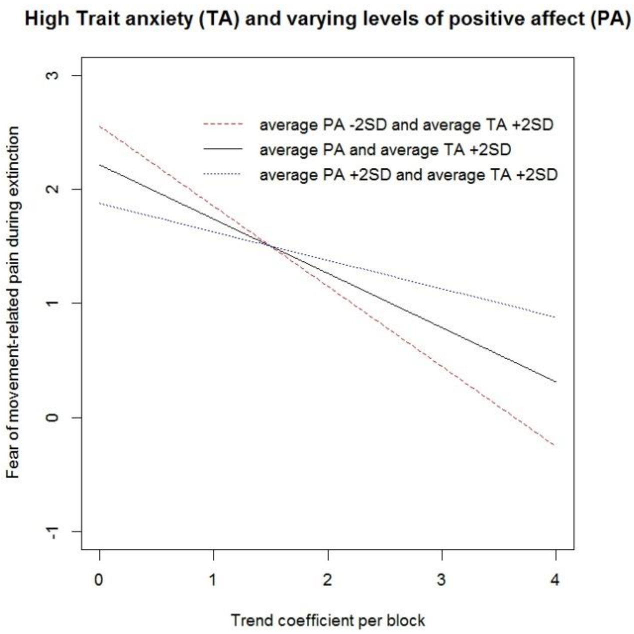


Table 1. *Multilevel regression predicting baseline-corrected fear of movement-related pain ratings during the extinction for the CS+ and the CS- movements for varying levels of positive affect (PA).*

Coefficient	Description effect	Estimate	Standard error	*p*-value
$\mu^{(+)}$	Average fear rating for CS+ movement on first extinction block for persons with mean PA level	-2.39	0.28	<.0001
$\beta_{T}^{(+)}$	Average change in fear rating per block for CS+ movement for persons with mean PA level	-0.51	0.07	<.0001
$\beta_{PA}^{(+)}$	Average change in fear rating for CS+ movement in first extinction block if PA level increases one SD	-0.53	0.28	0.058
$\beta_{TxPA}^{(+)}$	Change in slope of linear trend for CS+ movement if PA level increases one SD	0.10	0.07	0.147
$\mu^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with mean PA level	1.23	0.28	<.0001
$\beta_{T}^{(-)}$	Average change in fear rating per block for CS- movement for persons with mean PA level	-0.27	0.07	<.0001
$\beta_{PA}^{(-)}$	Average change in fear rating for CS- movement in first extinction block if PA level increases one SD	-0.39	0.28	0.158
$\beta_{TxPA}^{(-)}$	Change in slope of linear trend for CS- movement if PA level increases one SD	0.16	0.07	0.017
σ_{θ}^{2}	Between subject variability in fear ratings	2.79	0.59	<.0001
σ_{ε}^{2}	Within subject variability in fear ratings	2.49	0.16	<.0001
R^2	Explained proportion of variance in fear ratings	.77		

Table 2. *Multilevel regression predicting baseline-corrected fear of movement-related pain ratings during the extinction for the CS+ and the CS- movements for varying levels of trait anxiety (TA).*

Coefficient	Description effect	Estimate	Standard error	*p*-value
$\mu^{(+)}$	Average fear rating for CS+ movement on first extinction block for persons with mean TA level	-2.39	0.28	<.0001
$\beta_{T}^{(+)}$	Average change in fear rating per block for CS+ movement for persons with mean TA level	-0.51	0.07	<.0001
$\beta_{TA}^{(+)}$	Average change in fear rating for CS+ movement in first extinction block if TA level increases one SD	0.37	0.28	0.178
$\beta_{TxTA}^{(+)}$	Change in slope of linear trend for CS+ movement if TA level increases one SD	-0.13	0.07	0.058
$\mu^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with mean TA level	1.23	0.28	<.0001
$\beta_{T}^{(-)}$	Average change in fear rating per block for CS- movement for persons with mean TA level	-0.27	0.07	<.0001
$\beta_{TA}^{(-)}$	Average change in fear rating for CS- movement in first extinction block if TA level increases one SD	0.57	0.28	0.041
$\beta_{TxTA}^{(-)}$	Change in slope of linear trend for CS- movement if TA level increases one SD	-0.16	0.07	0.021
σ_{θ}^{2}	Between subject variability in fear ratings	2.80	0.59	<.0001
σ_{ε}^{2}	Within subject variability in fear ratings	2.50	0.16	<.0001
R^2	Explained proportion of variance in fear ratings	.77		

Table 3. *Planned contrasts for model including PA and TA separately*.

Coefficient	Description effect in PA model	Estimate	Standard error	*p*-value
$\mu^{(+)} - \mu^{(-)}$	Difference between average fear ratings for CS+ movement and CS- movement on first extinction block for persons with mean PA level	-3.62	0.23	<.0001
$\beta_T^{(+)} - \beta_T^{(-)}$	Difference in slope of linear trend for CS+ and CS- movement for persons with average PA level	-0.25	0.09	0.009
$\mu^{(-)} - \beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a PA level of 1 SD below average	1.62	0.39	<.0001
$\mu^{(-)} - 2\beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a PA level of 2 SDs below average	2.02	0.62	0.001
$\mu^{(-)} + \beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a PA level of 1 SD above average	0.84	0.39	0.032
$\mu^{(-)} + 2\beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a PA level of 2 SDs above average	0.45	0.62	0.470
$\beta_T^{(-)} - \beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a PA level of 1 SD below average	-0.43	0.09	<.0001
$\beta_T^{(-)} - 2\beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a PA level of 2 SDs below average	-0.59	0.15	<.0001
$\beta_T^{(-)} + \beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a PA level of 1 SD above average	-0.11	0.09	0.255
$\beta_T^{(-)} + 2\beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a PA level of 2 SDs above average	0.05	0.15	0.724

Coefficient	Description effect in TA model	Estimate	Standard error	*p*-value
$\mu^{(+)} - \mu^{(-)}$	Difference between average fear ratings for CS+ movement and CS- movement on first extinction block for persons with mean TA level	-3.62	0.23	<.0001
$\beta_T^{(+)} - \beta_T^{(-)}$	Difference in slope of linear trend for CS+ and CS- movement for persons with average TA level	-0.25	0.09	0.009
$\mu^{(-)} - \beta_{TA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a TA level of 1 SD below average	0.66	0.39	0.091
$\mu^{(-)} - 2\beta_{TA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a TA level of 2 SDs below average	0.09	0.62	0.880
$\mu^{(-)} + \beta_{TA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a TA level of 1 SD above average	1.80	0.39	<.0001

$\mu^{(-)} + 2\beta_{TA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with a TA level of 2 SDs above average	2.37	0.62	0.0001
$\beta_{T}^{(-)} - \beta_{TxTA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a TA level of 1 SD below average	-0.11	0.09	0.234
$\beta_{T}^{(-)} - 2\beta_{TxTA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a TA level of 2 SDs below average	0.04	0.15	0.776
$\beta_{T}^{(-)} + \beta_{TxTA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a TA level of 1 SD above average	-0.42	0.09	<.0001
$\beta_{T}^{(-)} + 2\beta_{TxTA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with a TA level of 2 SDs above average	-0.58	0.15	0.0001

Table 4. *Multilevel regression predicting baseline-corrected fear of movement-related pain ratings during the extinction for the CS+ and the CS- movements for varying levels of positive affect (PA) and varying levels of trait anxiety (TA) combined.*

Coefficient	Description effect	Estimate	Standard error	*p*-value
$\mu^{(+)}$	Average fear rating for CS+ movement on first extinction block for persons with mean PA and TA level	-2.39	0.28	<.0001
$\beta_{T}^{(+)}$	Average change in fear rating per block for CS+ movement for persons with mean PA and TA level	-0.51	0.07	<.0001
$\beta_{PA}^{(+)}$	Average change in fear rating for CS+ movement in first extinction block if PA level increases one SD and if TA level is average	-0.45	0.31	0.151
$\beta_{TA}^{(+)}$	Average change in fear rating for CS+ movement in first extinction block if TA level increases one SD and if PA level is average	0.17	0.31	0.583
$\beta_{TxPA}^{(+)}$	Change in slope of linear trend for CS+ movement if PA level increases one SD and if TA level is average	0.05	0.07	0.505
$\beta_{TxTA}^{(+)}$	Change in slope of linear trend for CS+ movement if TA level increases one SD and if PA level is average	-0.10	0.07	0.162
$\mu^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with mean PA and TA level	1.23	0.28	<.0001
$\beta_{T}^{(-)}$	Average change in fear rating per block for CS- movement for persons with mean PA and TA level	-0.27	0.07	<.0001
$\beta_{PA}^{(-)}$	Average change in fear rating for CS- movement in first extinction block if PA level increases one SD and if TA level is average	-0.17	0.31	0.587
$\beta_{TA}^{(-)}$	Average change in fear rating for CS- movement in first extinction block if TA level increases one SD and if PA level is average	0.49	0.31	0.115
$\beta_{TxPA}^{(-)}$	Change in slope of linear trend for CS- movement if PA level increases one SD and if TA level is average	0.11	0.07	0.129
$\beta_{TxTA}^{(-)}$	Change in slope of linear trend for CS- movement if TA level increases one SD and if PA level is average	-0.10	0.07	0.163
σ_{θ}^{2}	Between subject variability in fear ratings	2.84	0.60	<.0001
σ_{ε}^{2}	Within subject variability in fear ratings	2.47	0.16	<.0001
R^2	Explained proportion of variance in fear ratings	.77		

Table 5. *Planned contrasts for model including both PA and TA.*

Coefficient	Description effect	Estimate	Standard error	*p*-value
$\mu^{(+)} - \mu^{(-)}$	Difference between average fear ratings for CS+ movement and CS- movement on first extinction block for persons with mean TA and PA level	-3.62	0.23	<.0001
$\beta_T^{(+)} - \beta_T^{(-)}$	Difference in slope of linear trend for CS+ and CS- movement for persons with average TA and PA level	-0.25	0.09	0.009
$\beta_T^{(-)} + \beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with PA level of 1 SD above average and average TA level	-0.15	0.10	0.122
$\beta_T^{(-)} - \beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with PA level of 1 SD below average and average TA level	-0.38	0.10	0.0001
$\beta_T^{(-)} - \beta_{TxTA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with average PA level and TA level 1 SD below average	-0.16	0.10	0.101
$\beta_T^{(-)} + \beta_{TxTA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with average PA level and TA level 1 SD above average	-0.37	0.10	0.0002
$\mu^{(-)} + 2\beta_{TA}^{(-)} - 2\beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with PA level of 2 SDs below average and TA level of 2 SDs above average	2.56	0.71	0.0003
$\mu^{(-)} + 2\beta_{TA}^{(-)} - \beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with PA level of 1 SD below average and TA level of 2 SDs above average	2.39	0.62	0.0001
$\mu^{(-)} + 2\beta_{TA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with average PA level and TA level of 2 SDs above average	2.22	0.68	0.001
$\mu^{(-)} + 2\beta_{TA}^{(-)} + \beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with PA level of 1 SD above average and TA level of 2 SDs above average	2.05	0.86	0.018
$\mu^{(-)} + 2\beta_{TA}^{(-)} + 2\beta_{PA}^{(-)}$	Average fear rating for CS- movement on first extinction block for persons with PA level of 2 SDs above average and TA level of 2 SDs above average	1.88	1.10	0.088
$\beta_T^{(-)} + 2\beta_{TxTA}^{(-)} - 2\beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with PA level of 2 SDs below average and TA level of 2 SDs above average	-0.70	0.17	<.0001
$\beta_T^{(-)} + 2\beta_{TxTA}^{(-)} - \beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with PA level of 1 SD below average and TA level of 2 SDs above average	-0.59	0.15	<.0001
$\beta_T^{(-)} + 2\beta_{TxTA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with average PA level and TA level of 2 SDs above average	-0.48	0.16	0.004
$\beta_T^{(-)} + 2\beta_{TxTA}^{(-)} + \beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with PA level of 1 SD above average and TA level of 2 SDs above average	-0.36	0.21	0.078
$\beta_T^{(-)} + 2\beta_{TxTA}^{(-)} + 2\beta_{TxPA}^{(-)}$	Slope of linear trend in fear rating for CS- movement for persons with PA level of 2 SDs above average and TA level of 2 SDs above average	-0.25	0.26	0.343

Supplementary Table 1. *Frequency table for the categorization of "high" versus "low" positive affect (PA) and trait anxiety (TA) based on the present healthy study sample.*

Total sample (*N* = 56)	Frequency	Percentage	Cumulative Frequency	Cumulative Percentage
Positive affect				
PA≤ -2SD	1	1.79	1	1.79
-2 SD<PA ≤ -1 SD	7	12.50	8	14.29
-1 SD<PA≤ +1 SD	40	71.43	48	85.71
+1 SD<PA≤+2 SD	5	8.93	53	94.64
PA>+2SD	3	5.36	56	100.00
Trait anxiety				
TA≤ -2SD	0	0	0	0
-2 SD<TA ≤ -1 SD	9	16.07	9	16.07
-1 SD<TA≤ +1 SD	37	66.07	46	82.14
+1 SD<TA≤+2 SD	7	12.50	53	94.64
TA>+2SD	3	5.36	56	100.00

Supplementary Table 2. *Descriptives of the questionnaires and pain-US intensity measures.*

Total sample (N = 56)		
	M	*SD*
Age	19.07	2.80
Self-reported stimulus intensity (*1= no pain;10 = worst imaginable pain*)	7.99	0.28
Physical stimulus intensity (*in mA*)	25.50	10.82
Trait anxiety (TA)	41.02	8.75
Positive Affect (PA)	33.82	6.08
Negative Affect (NA)	20.25	6.07

Note – TA = total score on the trait version of the State-Trait Anxiety Inventory; PA = total score on the Positive Affect scale of the Positive and Negative Affect Schedule; NA = total score on the Negative Affect scale of the Positive and Negative Affect Schedule; *M* = mean; *SD* = standard deviation.

Supplementary Table 3. *Spearman rank correlation coefficients for the questionnaires and pain-US intensity measures for the total sample.*

Total sample (*N* = 56)	TA	PA	NA	$Pain_{subj}$	$Pain_{mA}$
TA	1				
PA	-0.44*	1			
NA	0.73*	-0.22	1		
$Pain_{subj}$	-0.15	0.18	-0.05	1	
$Pain_{mA}$	0.11	-0.02	0.19	-0.15	1

Note – TA = total score on the trait version of the State-Trait Anxiety Inventory; PA = total score on the Positive Affect scale of the Positive and Negative Affect Schedule; NA = total score on the Negative Affect scale of the Positive and Negative Affect Schedule; $Pain_{subj}$ = self-reported stimulus intensity; $Pain_{mA}$ = physical stimulus intensity in mA; *$p < .001$.

The multilevel model for testing the effect of trait anxiety and trait positive affect on fear of movement-related pain ratings during the extinction phase

To describe the model, we assume that y_{ijk} represents the fear of movement-related pain rating obtained during the extinction phase when subject *i (i*=1,..,56*)* responds to trials in block *j (j*=e1,..e5*)* of movement type *k* (CS+ or CS-). To account for differences obtained during the acquisition phase, we corrected the fear of movement-related pain ratings using the values during the last block of the acquisition phase (y_{ik}^{last}) as a baseline. In other words, the variable $y_{ijk}^{*} = y_{ijk} - y_{ik}^{last}$ is used as the dependent variable in our analysis.

It is assumed that fear of movement-related pain ratings decrease linearly in the subsequent blocks. In particular, the linear trend variable T_j (which equals 0,1,2,3,4 for blocks *j*=e1,e2,e3,e4,e5) is used to model a linear trend of the fear of movement-related pain in the subsequent blocks. The standardized variables PA_i and TA_i respectively represent the trait positive affect (PA) and trait anxiety (TA) scores of subject *i*. To investigate whether the strength of the linear trend depends on the PA (or TA) level of a subject, we include an interaction between PA (or TA) and the linear trend variable.

For the case of trait positive affect, the following model is specified:

$$y_{ijk}^{*} = \theta_i + \mu^{(k)} + \beta_T^{(k)} T_j + \beta_{PA}^{(k)} PA_i + \beta_{TxPA}^{(k)} T_j PA_i + \varepsilon_{ijk}$$

Note that the model includes specific regression coefficients for each of the movement types (CS+ and CS-) and that $\theta_i \sim N(0, \sigma_\theta^2)$ is a random effect term that measures the average level of the baseline corrected fear of movement-related pain ratings of subject *i* across blocks for the two types of movements. The random effect term is added to model the dependencies between the observations of the same subject.

This model should be interpreted as follows:

$\mu^{(+)}$ and $\mu^{(-)}$ = fear of movement-related pain scores respectively for the CS+ movement and the CS- movement on the first extinction block (e1) corrected for the end of acquisition (a3) for individuals with a mean level of PA (i.e. the value 0 for the standardized PA variable); 0 = no average change in fear of movement-related pain scores from a3 to e1, negative value = average decrease in fear of movement-related pain scores from a3 to e1, positive value = average increase in fear of movement-related pain scores from a3 to e1.

$\beta_T^{(+)}$ and $\beta_T^{(-)}$ = regression coefficient of the linear trend variable respectively for the CS+ movement and CS- movement which indicates the average change in fear of movement-related fear scores per block for individuals with a mean level of PA (i.e. the value 0 for the standardized PA variable); 0 = no change in fear of movement-related pain scores, negative value = decrease in fear of movement-related pain scores, positive value = increase in fear of movement-related pain scores.

$\beta_{PA}^{(+)}$ and $\beta_{PA}^{(-)}$ = regression coefficient respectively for the CS+ movement and CS- movement indicates the average change in fear of movement-related fear at the first block of extinction (e1) if the PA score increases one standard deviation; 0 = no average change in fear of movement-related pain scores, negative value = decrease in fear of movement-related pain scores, positive value = average increase in fear of movement-related pain scores.

$\beta_{TxPA}^{(+)}$ and $\beta_{TxPA}^{(-)}$ = regression coefficient of the interaction between the linear trend and the (standardized) PA score respectively for the CS+ movement and the CS- movement which indicates the change in the slope of the linear trend coefficient if the PA score increases with one standard deviation.

σ_{θ}^{2} and σ_{ε}^{2} = variability of the fear of movement-related pain scores respectively between and within subjects.

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